इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 15850 (2009): Nuclear grade boron carbide [CHD 30: Nuclear Materials]

"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

BLANK PAGE

BRUTUM FULMEN

IGNORANTIA
JURIS
NON EXCUSAT

PROTECTED BY COPYRIGHT

IS 15850 : 2009

भारतीय मानक

नाभिकीय ग्रेड बोरोन कारबाइड — विशिष्टि

Indian Standard

NUCLEAR GRADE BORON CARBIDE — SPECIFICATION

ICS 27.120.10;71.060.01

© BIS 2009

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

January 2009

Price Group 4

Nuclear Materials Sectional Committee, CHD 30

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Nuclear Materials Sectional Committee had been approved by the Chemical Division Council.

Boron carbide (chemical formula B_4C) is an extremely hard ceramic material used in tank armor, bulletproof vests, and numerous industrial applications with a hardness of 9.3 on the mohs scale. Its ability to absorb neutrons without forming long lived radionuclides makes the material attractive as an absorbent for neutron radiation arising in nuclear power plants. Boron carbides are used for controlling the rate of nuclear reactions in the nuclear reactors and thus play a very crucial role in reactor control.

There is no ISO Standard on the subject. The standard is prepared based on the indigenous manufacturers' data/practices prevalent in the field in India.

The composition of the Committee responsible for formulating this standard is given in Annex F.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

NUCLEAR GRADE BORON CARBIDE — SPECIFICATION

1 SCOPE

This standard prescribes the requirements and methods of tests for boron carbide (B_4C), used in the form of powder, pellets, or in any dispersed state in the control material in nuclear reactors.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
1493 : 1959	Methods of chemical analysis of iron ores
3025 : 1964	Methods of sampling and test (physical and chemical) for water used in industry
6226 (Part 1) : 1994	Recommendations for apparatus for chemical analysis of metals: Part 1 Apparatus for determination of carbon by direct combustion (*first revision*)
8883 (Part 1) : 2005	Methods of sampling chemicals and chemical products: Part 1 General requirements and precautions (*first revision*)
8883 (Part 2/ Sec 1) : 1978	Methods of sampling chemicals and chemical products: Part 2 Sampling equipment, Section 1 For solids
9931 : 1981	Mercurimetric method for determination of chloride in inorganic chemicals
10614 : 1983	Method for atomic absorption spectrophotometric determination of sodium and potassium
12046 : 1987	Method for determination of manganese by atomic absorption spectrophotometry
12491 : 1988	Method for determination of magnesium by atomic absorption spectrophotometry
13320 : 1992	Method for determination of iron by atomic absorption spectrophotometry — Test method

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Nuclear Reactor — A device in which a self-sustaining nuclear fission reaction can be maintained and controlled.

3.2 Reactor Control — The intentional variations of the reaction rate in a nuclear reactor obtained by adjustment of reactivity to achieve or maintain a desired state of operation.

4 REQUIREMENTS

4.1 General

The material shall be in the form of black powder or crystalline, free from odour, dirt, foreign matter and visible impurities.

4.2 Chemical Requirements

4.2.1 The material shall conform to the isotopic content of the natural boron, that is, ^{10}B shall be 19.9 ± 0.3 atom percent and ^{11}B shall be 80.1 ± 0.3 atom percent when tested in accordance with the method given in Annex A. The material shall also conform to the requirements given in Table 1 when tested in accordance with the methods prescribed in col 4 of the table. The sample is to be processed as per the procedure given in Annex A and the processed sample is to be taken for further analysis.

4.2.2 The material shall also conform to the requirements prescribed in Table 1 when tested according to the methods referred in col 4 or 5 of Table 1.

5 PACKING AND MARKING

5.1 Marking

The containers shall be securely closed and bear legibly and indelibly the following particulars:

Table 1 Requirements for Nuclear Grade Boron Carbide

(*Clauses* 4.2.1 *and* 4.2.2)

Sl No. (1)	Characteristic (2)	Requirement (3)	Method of Test, Ref to Cl/IS No. (4)	Method of Test, Ref to Annex (5)
i)	Total boron, percent by mass, *Min*	77	—	B
ii)	Chloride (as Cl), percent by mass, *Max*	0.007 5	9931	—
iii)	Sodium (as Na), percent by mass, *Max*	0.01	10614	—
iv)	Iron (as Fe), percent by mass, *Max*	0.02	13320	—
v)	Total carbon, percent by mass, *Min*	20.5	—	C
vi)	Fluoride (as F), percent by mass, *Max*	0.002 5	23 of 3025	—
vii)	Silicon (as Si), percent by mass, *Max*	0.1	1493	—
viii)	Aluminium (as Al), percent by mass, *Max*	0.3	—	D
ix)	Magnesium (as Mg), percent by mass, *Max*	0.15	12491	—
x)	Cobalt (as Co), percent by mass, *Max*	0.005	—	E
xi)	Manganese (as Mn), percent by mass, *Max*	0.01	12046	—

a) Name of the material;

b) Minimum assay, maximum impurity concentration and 10B/11B ratio;

c) Gross and net mass;

d) Date of manufacture and batch number; and

e) Name of the manufacturer and his recognized trade-mark, if any.

5.1.1 *BIS Certification Marking*

The product may also be marked with the Standard Mark.

5.1.1.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

5.2 Packing

Unless otherwise agreed to between the purchaser and the supplier, the powder shall be packed in suitable containers such as HDPE bottles and sealed under moisture-proof conditions.

6 SAMPLING AND CRITERIA FOR CONFORMITY

6.1 The samples shall be collected according to the method prescribed in IS 8883 (Part 1) and with the help of the equipment prescribed in IS 8883 (Part 2/Sec 1).

6.2 Criteria for Conformity

6.2.1 Sampling plans to meet acceptance criteria and inspection and measurement procedures that describe the method of compliance with this specification shall be established by the seller and submitted to the buyer for approval.

6.2.2 Each sample taken shall be sufficient to perform the following in the event they are necessary or desired by the buyer.

6.2.2.1 Quality verification tests by the seller.

6.2.2.2 Acceptance tests by the buyer.

6.2.2.3 Referee tests in the event these become necessary.

6.2.2.4 Retention of archive samples by the seller.

6.3 Archive samples shall be retained by the seller for a period of time specified by the buyer and delivered to the buyer upon request.

ANNEX A

(*Clause* 4.2.1)

THERMAL IONIZATION MASS SPECTROMETRIC METHOD FOR DETERMINATION OF ISOTOPIC CONTENT OF BORON

A-1 APPARATUS

A-1.1 Thermal Ionization Mass Spectrophotometer

A-2 REAGENTS

A-2.1 Demineralized Water

A-2.2 Sodium Carbonate

A-3 PROCEDURE

Boron carbide is brought into solution after fusion with sodium carbonate. The melt is dissolved in demineralized water and filtered to remove the undissolved residue. The solution is acidified and heated to remove CO_2. The solution is then evaporated and redissolved in water and concentrated into a tiny drop. The concentrated residue containing about 2 μg of boron is treated with demineralized water and again concentrated to a tiny drop. Using a capillary tube, the concentrate is loaded on a degassed rhenium filament and dried electrically. The loaded filament is taken inside the mass spectrometer where evaporation and thermal ionization of the sample at 700 - 800°C gives rise to $Na_2BO_2^+$ ions. The molecular ions of mass 88 and 89 corresponding to B^{10} and B^{11} are mass analysed by a 90 degree sector magnetic field and the ion intensities are measured by a suitable detector (Daly scintillation detector or Faraday Cup). The ratio of ion intensities gives the isotope ratio. The precision of the measurement is 0.05 - 0.1 percent.

NOTE — The suitable chemical form for isotopic analysis of boron is alkali metal borate, usually the sodium tetraborate.

ANNEX B

[*Table* 1, *Sl No.* (i)]

TOTAL BORON IN BORON CARBIDE

B-1 REAGENTS

B-1.1 Mannitol or Sorbitol, neutral. The reagent shall satisfy the test given in **B-1.1.1**.

B-1.1.1 Five grams of mannitol/sorbitol dissolved in 50 ml of carbon dioxide free water shall require for neutralization not more than 0.3 ml of 0.02 N sodium hydroxide solution using phenolphthalein as indicator.

B-1.2 Standard Sodium Hydroxide Solution, 1 N.

B-1.3 Phenolphthalein Indicator Solution — Dissolve 0.1 g of the phenolphthalein in 60 ml of rectified spirit and dilute with water to 100 ml.

B-2 PROCEDURE

Weigh accurately about 2 g of the dried boron carbide and bring into solution after fusion with sodium carbonate. Dissolve the molten mass in about 120 ml of demineralized water and filtered to remove the undissolved residue, if any. Add about 15 g of mannitol or sorbitol and 0.4 ml of phenolphthalein. Titrate with standard sodium hydroxide solution to a distinct pink colour.

B-3 CALCULATION

$$\text{Boron Carbide, percent by mass} = \frac{3.481 \times V}{M}$$

where

V = volume in ml of standard sodium hydroxide solution used in the titration, and

M = mass in g of the dried material taken for the test.

ANNEX C

[*Table* 1, *Sl No.* (v)]

DETERMINATION OF TOTAL CARBON IN BORON CARBIDE BY COMBUSTION AND GRAVIMETRY

C-1 PRINCIPLE

Known weight of B_4C is mixed with suitable flux material and is subjected to combustion at about 1 500°C in oxygen flow. Carbon dioxide liberated is purified and is absorbed in a known amount of ascarite or barium/calcium hydroxide solution. The difference in weight gives the amount of carbon dioxide and hence total carbon present in boron carbide.

C-2 APPARATUS

C-2.1 The apparatus recommended in IS 6226 (Part 1) may be used.

NOTE — Instead of the resistance furnace, an induction furnace may also be used

C-2.2 Boat/Crucible

Alumina boat/crucible of precise dimensions for accommodating in the resistance/induction furnace. Preignite the boats/crucibles in air or oxygen in a furnace for an hour at 1 100°C and store in a desiccator and check for consistency of the blank value.

C-3 REAGENTS

C-3.1 Oxygen, purity more than 99.5 percent.

C-3.2 Ascarite or Soda Lime, size 0.80 to 2.00 mm. dia 20 to 30 mesh.

C-3.3 Anhydrous Magnesium Perchlorate, $Mg(ClO_4)_2$.

C-3.4 Flux, tin.

C-3.5 Barium/Calcium Hydroxide (0.1 M) Solution

C-4 PROCEDURE

C-4.1 Assemble the apparatus. Switch on the furnace, if it is a resistance furnace, and allow it to attain a temperature of 1 450 ± 50°C, all the while passing oxygen through the apparatus so that it bubbles freely at the exit end of the train. Disconnect the absorption bulb, keep in a desiccator till it attains room temperature and take the initial weight. Repeat the operation till a constant mass is obtained.

NOTE — As an alternative, instead of absorbing carbon dioxide in ascarite enclosed in absorption bulb, the same can be absorbed in the barium/calcium hydroxide (0.1 M) absorber solution.

C-4.2 Weigh accurately a known amount (about 100 - 200 mg) of boron carbide into an alumina crucible. The particle size should be below 100 mesh. Transfer the sample to the preignited combustion boat covered at the bottom with a thin layer of calcined alumina. Spread the sample evenly over the top of the alumina and cover it with tin flux in 1 : 4 ratios. Introduce the boat slowly in the hot zone of the combustion tube.

C-4.3 In the case of induction heating, weigh to the nearest 0.001 g, 0.9 to 1.1 g of the sample and transfer it to a preignited crucible. Add an equal quantity of the flux. Place the crucible in position on the pedestal post of the furnace, raise to the combustion position and lock the system. Pass oxygen through the system and ignite the sample.

C-4.4 Maintain a rapid flow of oxygen (800 to 1 000 ml/min) throughout the combustion, then reduce to 400 to 500 ml/min and maintain it for another 6 to 8 min in order to sweep out the carbon dioxide.

C-4.5 Remove the absorption bulb and weigh it after keeping it in desiccator till it attains room temperature. The increase in mass of the bulb represents the mass of carbon dioxide.

C-4.6 Remove the boat or crucible and examine for any incomplete combustion. If the sample is not thoroughly fused, repeat the determination with a fresh sample.

C-4.7 Blank

Make a blank determination following the procedure specified in **C-4.2** to **C-4.6** and using same quantity of reagents except the sample.

C-5 CALCULATION

Calculate the carbon, percent by mass, in sample as follows:

$$\text{Carbon, percent by mass} = \frac{(A-B)}{C} \times 27.29$$

where

A = increase of mass, in g, of the absorption bulb from the sample;

B = increase of mass, in g, of the absorption bulb from the blank determination; and

C = mass, in g, of the sample taken.

ANNEX D

[*Table* 1, *Sl No.* (viii)]

DETERMINATION OF ALUMINIUM IN BORON CARBIDE BY ATOMIC ABSORPTION SPECTROMETERY

D-1 PRINCIPLE

Boron carbide is brought into solution after fusion with sodium carbonate. The solution is then introduced into acetylene-nitrous oxide flame and the intensity of line at 309.3 nm corresponding to Al is measured.

D-2 APPARATUS

D-2.1 Atomic Absorption Spectrometer

Equipped with a monochromatic radiation source such as aluminium hollow cathode lamp, a monochromater to isolate the 309 nm resonance line, quartzite an atomization source such as a nitrous oxide.

D-2.2 Platinum Crucible

D-2.3 Volumetric Flask, 100 cc, 6 Nos.

D-3 REAGENTS

D-3.1 Hydrochloric Acid, 40 percent (*m/v*).

D-3.2 Sodium Carbonate, solid.

D-3.3 Dilute Hydrochloric Acid, 1 : 1 (*v/v*).

D-3.4 Standard Aluminium Solution (1 ml = 1 000 µg Al) — Dissolve 1.00 g of aluminium foil (purity 99.9 percent, Min) volume of dilute hydrochloric acid (1 : 1) and dilute to one litre with water.

D-4 PROCEDURE

D-4.1 Weigh accurately a known amount of boron carbide (0.2 g). Transfer it to a platinum crucible. Fuse the residue with 1 g of sodium carbonate slowly to a clear melt. Cool and extract the melt with 10 to 15 ml of dilute hydrochloric acid (1:1). Boil the extracted mass to get a clear solution, cool and make up to 250 ml in a calibrated volumetric flask.

D-4.2 Preparation of Calibration and Blank Solutions

D-4.2.1 Take six number of 100-ml volumetric flasks and to each flask add 0, 1, 2, 3, 4 and 5 ml of standard aluminium solution (*see* **D-3.4**). Add to each solution the same amount of sodium carbonate as taken for boron carbide fusion. Dilute to the mark with water and mix well. The zero member of this series will serve as the reference solution.

D-4.2.2 Prepare a blank solution using same quantities of all the reagents and following the procedure as specified in **D-4.2.1** but without sample.

D-4.2.3 *Adjustment of the Atomic Absorption Spectrometer*

Follow the instructions of the manufacturer in preparing the instrument. Switch on the instrument and the aluminium hollow cathode lamp. Fit the correct burner for nitrous oxide-acetylene flame and light the appropriate flame (lean). Wait for about 20 min for stabilization. Set the wavelength at 309 nm. Optimize instrument response by adjusting the wavelength, fuel, air, burner and nebulizer while aspirating the highest calibration solution. As the sensitivity varies from instrument to instrument the concentration of the standard series and of the test solution should be adjusted accordingly. At the same time check the linearity of the calibration curve. Aspirate water and one of the calibration solutions repeatedly to ensure that there is no drift of absorbance. Finally aspirate water and set the absorbance to zero reading.

D-4.2.4 *Atomic Absorption Measurement*

D-4.2.4.1 Aspirate first the blank solution and then the calibration solution in increasing order, aspirating water between each aspiration of the solution and record the absorbance reading. Then aspirate the test sample and note the absorbance. Each aspiration should be made at least three times and take the average value. Solids which build up on the burner slit must be removed, otherwise they will cause a decrease of sensitivity.

D-4.2.4.2 Deduct the blank value from the absorbance of the standard as well as the test solution.

D-4.2.4.3 Prepare a calibration curve by plotting the absorbance value of the standard solutions against the concentration in the µg/ml of the element.

D-4.2.4.4 Compute the concentration of the test solution (corrected for the blank) to µg of the element per ml from the calibration curve.

D-4.3 Calculation

Calculate the percentage of aluminium content as follows:

$$\text{Aluminium, percent by mass} = \frac{A}{B \times 10^6} \times 100$$

where

A = concentration, in µg/ml, of aluminium; and

B = mass, in g, of the sample represented by the aliquot taken in the final test solution.

ANNEX E

[*Table* 1, *Sl No.* (x)]

DETERMINATION OF COBALT IN BORON CARBIDE

E-1 PRINCIPLE

A known amount of boron carbide is brought into solution after fusion with sodium carbonate. The anionic impurities and boron are separated employing a strong base anion exchange resin. Cobalt held up on the column is eluted in dilute HCl, concentrated and introduced into acetylene-air flame and the intensity of line at 240.7 nm corresponding to cobalt is measured.

E-2 APPARATUS

E-2.1 Atomic Absorption Spectrophotometer, with graphite furnace/carbon rod atomizer.

E-2.2 Burner

E-3 REAGENTS

E-3.1 A Strong Base Anion Exchange Resin

E-3.2 Sodium Carbonate, solid.

E-3.3 Hydrochloric Acid, 3 M.

E-3.4 Dilute Hydrochloric Acid, 1 : 1 (*v*/*v*).

E-3.5 Standard Cobalt Solution (1 ml = 100 µg Co) — Dissolve 0.403 4 g $CoCl_2$, $6H_2O$ (A.R.) in a litre of water, giving a solution containing 0.1 mg/ml cobalt.

E-3.6 Double Distilled Water

E-4 PROCEDURE

E-4.1 Weigh accurately a known amount of boron carbide (100 mg). Transfer it to a platinum crucible. Fuse the residue with 1 g of sodium carbonate slowly to a clear melt. Cool and extract the melt with 10 to 15 ml of dilute hydrochloric acid (1 : 1). Boil the extracted mass to get a clear solution and cool. Set up a strong base anion exchange resin 8-10 cm long and 0.8 to 1 cm diameter and condition with dilute hydrochloric acid. Transfer the dissolved melt on to the column and wash the column with distilled water. Boron elutes down. Wash the column with minimum two bed volumes. Reject the washings. Wash the column with about 10 ml of 3 M HCl and collect the washings in a fresh vial. Evaporate the washings collected and dissolve in distilled water.

NOTE — It should be mentioned that the volumes of eluants given above are only indicative and it may be necessary to optimize the elution steps during the ion exchange separation procedure.

E-4.2 Preparation of Calibration and Blank Solutions

E-4.2.1 Take six number 100-ml volumetric flasks and to each flask add 0, 1, 2, 3, 4 and 5 ml of standard cobalt solution (*see* **E-3.5**). Add to each solution the same amount of sodium carbonate as taken for boron carbide fusion. Dilute to the mark with water and mix well. The zero member of this series will serve as the reference solution.

E-4.2.2 Prepare a blank solution using same quantities of all the reagents and following the procedure as specified in **E-4.2.1** but without sample.

E-4.2.3 *Adjustment of the Atomic Absorption Spectrometer*

Follow the instructions of the manufacturer in preparing the instrument. Switch on the instrument and the cobalt hollow cathode lamp. Fit the correct burner for air-acetylene flame and light the appropriate flame (lean). Wait for about 20 min for stabilization. Set the wavelength at 240.7 nm. Optimize instrument response by adjusting the wavelength, fuel, air, burner and nebulizer while aspirating the highest calibration solution. As the sensitivity varies from instrument to instrument the concentration of the standard series and of the test solution should be adjusted accordingly. At the same time check the linearity of the calibration curve. Aspirate water and one of the calibration solutions repeatedly to ensure that there is no drift of absorbance. Finally aspirate water and set the absorbance to zero reading.

E-4.2.4 *Atomic Absorption Measurement*

E-4.2.4.1 Aspirate first the blank solution and then the calibration solution in increasing order, aspirating water between each aspiration of the solution and record the absorbance reading. Then aspirate the test sample and note the absorbance. Each aspiration should be made at least three times and take the average value. Solids which build up on the burner slit must be removed, otherwise they will cause a decrease of sensitivity.

E-4.2.4.2 Deduct the blank value from the absorbance of the standard as well as the test solution.

E-4.2.4.3 Prepare a calibration curve by plotting the absorbance value of the standard solutions against the concentration in the µg/ml of the element.

E-4.2.4.4 Compute the concentration of the test solution (corrected for the blank) to µg of the element per ml from the calibration curve.

E-5 CALCULATION

Calculate the percentage of cobalt content as follows:

$$\text{Cobalt, percent by mass} = \frac{C}{D \times 10^6} \times 100$$

where

C = concentration, in µg/ml, of cobalt; and

D = mass in g, of the sample represented by the aliquot taken in the final test solution.

ANNEX F

(*Foreword*)

COMMITTEE COMPOSITION

Nuclear Materials Sectional Committee, CHD 30

Organization	*Representative(s)*
Bhabha Atomic Research Centre, Mumbai	Dr V. Venugopal (***Chairman***)
Atomic Energy Regulatory Board, Mumbai	Shri S. P. Agarwal
Bhabha Atomic Research Centre (Environment Division), Mumbai	Dr (Smt) G. G. Pandit
Bhabha Atomic Research Centre (Radiochemistry & Isotope Group), Mumbai	Dr K. L. Ramakumar
Bharat Heavy Electricals Limited, Hyderabad	Shri K. Natarajan
Board of Radiation and Isotope Technology (BRIT), New Delhi	Dr N. C. Goomer
Defence Research & Development Organization, Jodhpur	Shri S. G. Vaijapurkar Dr Pradeep Narayan (*Alternate*)
Department of Atomic Energy, Nuclear Fuel Complex, Hyderabad	Dr B. N. Murthy Shri Y. Balaji Rao (*Alternate*)
Indian Rare Earths Limited, Mumbai	Shri V. K. Verma Shri A. K. Das (*Alternate*)
Indira Gandhi Centre for Atomic Research, Kalpakkam	Dr K. S. Viswanathan Dr K. Sankaran (*Alternate*)
Madras Atomic Power Station, Kalpakkam	Dr K. S. Krishna Rao
Ministry of Defence (DGQA), Pune	Shri K. U. K. Pillai Shri P. G. Date (*Alternate*)
Ministry of Defence (Institute of Nuclear Medicine and Allied Sciences), Delhi	Dr Ravi Kashyap Dr Anupal Mondal (*Alternate*)
Ministry of Environment and Forests, New Delhi	Dr A. Senthil Vel Dr Y. P. Kakar (*Alternate*)
Nuclear Power Corporation India Limited, Tarapur Atomic Power Station, Mumbai	Shri U. Ramamurthy Shri S. Bhattacharjee (*Alternate*)
Nuclear Power Corporation of India Limited, Mumbai	Shri H. D. Sharma Shri R. Y. Singh (*Alternate*)
Raja Rananna Centre for Advanced Technology, Indore	Representative
Rajasthan Atomic Power Station, Rajasthan	Shri P. K. Pal Shri S. L. Saini (*Alternate*)
Rajiv Gandhi Cancer Institute and Research Centre, Delhi	Prof P. S. Negi Shri R. K. Munjal (*Alternate*)
Saha Institute of Nuclear Physics, Kolkata	Prof Sudeb Bhattacharya Prof Susanta Lahiri (*Alternate*)
Shriram Institute of Industrial Research, Delhi	Dr A. K. Verma Shri Sanjay Rajput (*Alternate*)
Tata Institute of Fundamental Research, Mumbai	Prof H. C. Jain
Tata Memorial Centre, Mumbai	Representative
Uranium Corporation of India Limited, Jharkhand	Shri S. Siddique
Vikram Sarabhai Space Research Centre, Thiruvananthapuram	Representative
BIS Directorate General	Shri E. Devendar, Scientist F & Head (CHD) [Representing Director General (*Ex-officio*)]

Member Secretary

Shri N. K. Pal
Scientist E (CHD), BIS

MGIPF—897 Deptt of BIS/2008—[illegible]—300 Books

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act,* 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

This Indian Standard has been developed from Doc: No. CHD 30 (1431).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402

Telegrams: Manaksanstha
(Common to all offices)

Regional Offices: Telephone

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg
NEW DELHI 110002 — 2323 7617, 2323 3841

Eastern : 1/14 C. I. T. Scheme VI M, V. I. P. Road, Kankurgachi
KOLKATA 700054 — 2337 4899, 2337 8561, 2337 8626, 2337 9120

Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022 — 260 3843, 260 9285

Southern : C. I. T. Campus, IV Cross Road, CHENNAI 600113 — 2254 1216, 2254 1442, 2254 2519, 2254 2315

Western : Manakalaya, E9 MIDC, Marol, Andheri (East)
MUMBAI 400093 — 2832 9295, 2832 7858, 2832 7891, 2832 7892

Branches: AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISAKHAPATNAM.

Printed by the Manager, Govt. of India Press, Faridabad